EFFECTS OF HOLDING WALLEYE POLLOCK IN ICE AND REFRIGERATED SEAWATER ON THE QUALITY OF MODIFIED FILLET BLOCKS CONTAINING UP TO 30% MINCE

by

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ABSTRACT

Walleye pollock (*Theragra chalcogramma*) were removed from ice or refrigerated seawater (RSW) after 2, 4, and 6 days and processed into fillet blocks or fillet blocks containing 15% and 30% minced flesh. The quality of blocks with or without added mince remained highly acceptable to 7 months of frozen storage at -18C and was still acceptable at 12 months.. Adding mince to the fillet blocks did not accelerate the normal toughening of pollock flesh during frozen storage. Samples from fish held in ice had better quality than from fish held in RSW. The changes in dimethylamine and expressed thaw drip were related to the changes in sensory attributes of all blocks held at -18°C However, there were small changes in the control blocks held at -34°C.

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INTRODUCTION

In 1984, domestic processors of fishery products purchased over 300 million pounds of fillet and minced blocks mainly using cod and other members of the gadoid family such as walleye pollock (*Theragra chalcogramma*) (Thompson 1985). Over 99% of these blocks were imported. Part of the difficulty facing domestic production of pollock blocks is keeping production costs down to compete with foreign blocks. High speed filleting and skinning machines are available but even the best machines will produce a significant number of fillets with bones, patches of skin, and other defects. An alternative to the labor-intensive effort of manually removing the defects from these fillets is the use of mechanical flesh separators to produce a boneless, skinless mince that could be mixed with the fillets to form a modified block. Using pollock that had been previously frozen, Babbitt et al. (1984) demonstrated that an acceptable block could be produced using 20% mince but blocks with 50% mince were not acceptable. The purpose of this experiment was to determine the effects of incorporating minced flesh into blocks of fillets from pollock held in ice or refrigerated seawater.

METHODS AND MATERIALS

Materials

Approximately 1,500 kg of trawl-caught walleye pollock were delivered by chartered fishing vessel to the laboratory on 9 August 1984. The fish were caught 2 hours before delivery and were very uniform in size (768 + 22 g) The refrigerated seawater (RSW) tank was loaded with 450 kg of fish and 225 kg of 3.5% NaCl solution previously chilled to -1°C. The RSW temperature was maintained between 0 and -0.5°'C during the experiment. The remaining fish were iced in an insulated chest equipped with a drain. The fish-to-ice ratio was approximately 1: 1. The next day 250 kg of pollock from the ice chest were filleted. The fillets were skinned, washed, drained, trimmed of pin bones and defects, and sliced into l0-cm chunks to facilitate loading into cardboard-lined freezing forms or mixing with minced flesh. Minced flesh was prepared by passing the pin-bone trimmings and excess fillets through a Bibun[1] mincer equipped with an 8-mm drum. Chopped fillets were mixed by hand with appropriate amounts of minced flesh to form blocks containing 0, 15, or 30% mince. The blocks were frozen overnight at -40°C in a Dole plate freezer, overwrapped in 2-mil polybags, and then placed in master cartons. Several 8.4 kg blocks of chopped fillets with no mince were also prepared and stored at -34°C during the experiment to serve as control samples for the taste panel. One block each of chopped fillets containing 0, 15, or 30% mince was stored at -18°C and was referred to as the zero-holding time samples. At 2, 4, and 6 days of holding, 130 kg of fish were removed from ice and RSW. The three block forms were prepared from fish from each system and treated in the same manner as the zero-holding time samples. Approximately 1 kg of chopped fillets from each sample was frozen in plastic bags and stored at -34°C for chemical analysis. These samples, referred to as zero-time controls, were analyzed within 2 weeks of frozen storage.

1/ Reference to trade names does not imply endorsement by the National Marine Fisheries Service, NOAA.

Chemical Tests

Samples for chemical analysis were tempered overnight at 4°C and ground through a 6-mm plate while partially frozen. Analysis for trimethylamine (TMA) was performed by the method of Bullard and Collins (1980). Analysis for dimethylamine (DMA) by the method of Dowden (1938) and trimethylamine oxide (TMAO) by the method of Dyer et al. (1952) used the same 5% trichloroacetic acid (TCA) extract. At subsequent periods of frozen storage, the TCA extract was diluted with an additional 5% TCA to prevent an optical density greater than 1.5 in the analysis for DMA. Moisture, protein, and salt contents were determined by Association of Official Analytical Chemists (1980) methods. Expressed thaw drip of 2x2x7-cm portions cut from the blocks was determined by the method of Miyauchi (1962).

Sensory Analysis

At 30, 90, 220, and 375 days of frozen storage, portions were cut from each block for DMA and expressed thaw drip determinations as well as sensory analysis. The portions for sensory analysis measured 12x45x77 mm. A few days prior to each testing session, the still frozen portions ‘were battered and breaded using a commercial product (Golden Dipt). The portions were fried in vegetable oil in a deep-fat fryer for 5 minutes at 177°C, drained on paper towels, and served immediately to the panel. Panel sessions were held at 10 a.m. and 2 p.m. on consecutive days until all samples were evaluated. At each seating of the panel, the labelled control sample held at -34°C was served as a reference, then portions containing 0, 15, and 30% mince were evaluated. For example, the samples from fish that had been held 2 days in ice were always served at the same seating of the panel. The control was evaluated first, then the 0, 15, and 30% samples were examined in that order. The panelists were not informed of any order but were instructed to test the samples from left to right as they were arranged on their trays. At each period of frozen storage, the first seating of the panel examined the zero-holding time sample and the subsequent sessions examined, in order, the samples held for 2, 4, and 6 days in ice followed by those held in RSW for 2, 4, and 6 days.

Panelists evaluated color,' flavor, texture, and juiciness on a 7-point scale with the control sample assigned a value of 4 for each attribute. A score greater than 4 indicated that the panelist thought the sample was whiter, had better flavor, had a firmer texture (more resistant to chewing), or was more moist than the control. A score less than 4 indicated that the panelist thought the sample was darker, had a worse flavor, was softer or drier than the control. The panelists also judged the desirability of all samples including the control on a 9-point hedonic scale as follows: 9, very desirable; 5, neither like/dislike; 1, very undesirable. The judges were trained using portions with excellent and poor quality. The panelists were used at each session. The scores of the judges were subjected to analysis of variance (ANOVA) and Duncan's multiple range procedure (Sokal and Rohlf 1969; Bowman and Cahill 1975).

RESULTS AND DISCUSSION

Changes in moisture, salt, trimethylamlne ('TMA), dimechylamine (DMA), trimethylamine oxide (TMAO), and protein content of pollock held in ice and RSW are shown in Table 1. Salt content remained largely unchanged for pollock in ice but increased steadily for fish held in RSW. Salt uptake from holding the fish in RSW was similar but slightly lower than reported by Nelson (1982) and Reppond et al. (1985).

The TMA content remained relatively unchanged to 4 days in ice and was only 0.7 mg N/100 g at 6 days (Table 1). The TMA content was higher for fish held in RSW at 4 and 6 days. Pollock with high TMA values have been rated as having undesirable flavor or poor quality (Kramer and Nordin 1979; Reppond et al. 1985). The ammoniacal odor associated with spoiled fish was very strong in the RSW brine at 6 days and was easily detected in the frozen blocks of fillets from RSW on that day. Although TMA content was significantly correlated to undesirable flavor scores in other work (Kramer and Nordin 1979; Reppond and Collins 1983; Reppond et al. 1985), the correlation was not significant in this experiment. For the zero-time controls, DMA content remained relatively unchanged to 4 days in either medium but was higher at 6 days (Table 1). In a previous experiment (Reppond et al. 1985), DMA increased linearly with time of holding for fish in ice or RSW. Both TMA and DMA are formed from TMAO and a slight decrease in TMAO content occurred during the 6 days of fresh holding (Table 1).

The formation of DMA is accompanied by the formation of equimolar amounts of formaldehyde (FA) (Tokunaga 1964). The reaction of FA with muscle proteins causes denaturation and is thought to be the chief cause of toughening during frozen storage in the flesh of fish in the gadoid family (Tokunaga 1964, 1965; Babbitt et al. 1972; Hiltz et al. 1977; and Castell et al. 1973). In samples stored at -18°C, RSW samples tended to have more DMA than corresponding samples from fish held in ice (Table 2). Fish held 2 days in either system tended to have less DMA than at 4 or 6 days.

To determine the effect of prefreezing treatment on the rate of accumulation of DMA during frozen storage, a series of analyses of covariance were performed with medium holding time and block form used as covariants. The first step in evaluating the results was to test for the significance of the interaction term. If the interaction term proved significant, determination of the significance of the main effects is not possible. To overcome this problem, additional ANOVAs were performed on subsets of the data. For example, separate ANOVAs were performed on the DKA content of samples from fish held in ice and in RSW. If the interaction terms were not significant, then the significance of the main effects are determinable. The ANOVA on all the DMA data indicated that only the interaction term between medium and holding time was statistically significant (Table 3). The interaction term between time of fresh holding and block form was not significant which meant the manner in which block form affected DMA accumulation was not affected by holding time in a particular medium. These conclusions were supported by the results of separate ANOVAs for DMA values from fish held in each medium (Table 4). The interaction terms were not significant in either case, which allowed the determination of the significance of each of the main effects. For the data from fish held in ice, the ANOVA results indicated storage time, holding time, and block form affected DMA content. Since the interaction term was not significant, the rate of accumulation of DMA during frozen storage was not influenced by length of time in ice or by the addition of mince. In other words, more DMA was. formed in the blocks with mince than in the blocks with fillets during the freezing process, but the subsequent rate of DKA accumulation was the same. For RSW samples, time of storage and holding time affected DHA content but block form did not. As in the case of the samples in ice prior to processing, the interaction term was not significant so the rate of accumulation of DMA during frozen storage was not influenced by prefreezing history.

Additional ANOVAs were performed on the DMA data ‘from each of the block forms (Table 5). The interaction term for the blocks with no mince was significant, i.e., the rate of accumulation of DMA during frozen storage was different for samples’ from, different media or with different holding times. The prior explanation is thought to be more likely. For the blocks with 15% added mince, the interaction term was not significant and DMA content was affected by storage time and medium only. Iced samples had less DKA than RSW samples in the 15% blocks. For the blocks with 30% mince, the interaction term was not significant and only storage time affected DMA content in a significant manner.

Expressed thaw drip values (Table 6) were not subjected to ANOVA as duplicate determinations were not performed in most cases. Regression of thaw drip values on time of frozen storage revealed that, for the 2-day samples, holding medium had little or no effect (Fig. 1A). For the 4- and 6-day samples, however, the thaw drip was higher in the flesh from fish held in ice than the flesh of fish held in RSW (Fig. lB, C). These results support observations of others (Miyauchi 1963; Dyer 1969) that salt can reduce the thaw drip of frozen fillets. Addition of minced flesh tended to increase thaw drip values as reported by Babbitt et al. (1984).

Sensory Analysis

Color scores (Table 7) were affected by holding medium and block form but not by time of fresh holding or frozen storage according to the 4-way ANOVA (Table 8). Addition of mince lowered the color scores as expected. Although the decrease was not large, it was significant, especially for samples from fish held in ice (Table 9). The cooked fillets from pollock held in RSW were probably darker initially so the addition of mince did not significantly affect their color scores. The significant interaction between medium and time of holding had a similar explanation. The samples from iced fish tended to have lower color scores at 4 and 6 days of holding than at 2 days, whereas little difference was seen among the RSW samples due to time of holding (Table 9).

Mean color scores were significantly correlated with DMA content for fish held in ice but not for fish held in RSW (Table 10). The significant correlation between color and DMA content is interesting and DMA may be a good indicator for monitoring undesirable changes that occurred during frozen storage of pollock.

Flavor scores (Table 11) were significantly affected by all treatment factors except for block form which had an F value that was nearly significant at P = 0.056 (Table 8). Flavor scores decreased during frozen storage for all samples. Results from separate ANOVAs at each time of frozen storage (Table 12) revealed that differences between samples from different media were significant at only the last frozen storage period, which explains why the interaction between time of storage and medium was significant. Flavor scores generally decreased as holding time increased. The separate 3-way ANOVAs of flavor scores from samples from each medium indicated the addition of mince significantly reduced flavor scores for iced fish (Table 9). For fish held in RSW, the change was not significant. Mean flavor scores were significantly correlated with DMA content for fish from either medium (Table 10).

Texture scores (Table 13) were significantly affected by time of storage, medium, and block form but not by time of fresh holding (Table 8). Texture scores increased during frozen storage indicating the toughening of the muscle tissue common to fish from the gadoid family. Only a few samples averaged over 5.0 and none averaged over 6.0, which would be associated with an undesirably tough texture. The texture scores of samples from fish held in RSW tended to be higher than corresponding samples from fish held in ice. The addition of minced flesh resulted in increased texture scores (toughness), especially for fish held in RSW prior to processing (Table 9). The addition of minced flesh did not significantly change the texture score of iced fish, however. The lack of significant interactions between time of storage and other treatments was interpreted to mean that neither the prefreezing history of the fish nor the block form affected the toughening of the flesh during subsequent frozen storage.

Mean texture scores were correlated with thaw drip and DMA content for both samples of fish held in either system (Table 10). The correlations were interpreted as evidence of the denaturation of proteins by FA which is formed with DMA from TMAO. The correlation between DMA content and toughness scores has been noted elsewhere (Reppond et al. 1985).

Juiciness scores (Table 14) were significantly affected by storage time and block form but not by medium (Table 8). The effect of holding time was nearly significant. Increases in storage time and in the amount of added mince resulted in lower juiciness scores (portions were drier). The magnitude of the change was small, however, as no sample had an average score less than 3.1. The scores for iced pollock were not influenced by holding time. For RSW samples, the decrease in mean juiciness scores as holding time increased was more consistent. Perhaps the presence of salt had a deleterious effect in the RSW samples. Separate ANOVAs were performed on subsets of the data to determine the cause of the three statistically significant interactions. Separate ANOVAs for each period of frozen storage revealed that medium affected juiciness scores only at 375 days of frozen storage (Table 12). This treatment of the data explained the statistical origin of the storage time-medium interaction but did not provide any underlying phenomenological explanation. The interaction between medium and block form was probably caused by the relative insensitivity of juiciness scores of iced samples to block form as compared to samples from fish held in RSW (Table 13). A similar effect was noted with texture scores and may have been caused by the generally higher levels of DMA in fish held in RSW. The 3-way interaction between storage time, holding time, and medium may have been due to the storage time-holding time interaction being significant for iced fish but not for fish held in RSW (Table 9). As in the case of the storage time-medium interaction, no phenomenological cause was evident for such behavior.

Mean juiciness scores had a significant negative correlation with mean texture scores for samples from ice and RSW (Table 10). Firmer samples tended to be drier. The correlation coefficient was higher for RSW held samples than for those held in ice. Juiciness scores were not correlated with DMA content nor thaw drip values for samples from ice but were for samples from RSW.

Desirability scores (Table 15) reflected the overall hedonic response of the panelists to the total sensory attributes of the samples. All the treatments had a significant effect on desirability scores (Table 8). In general, desirability decreased as frozen storage time or fresh holding time increased (Table 11). RSW samples tended to have slightly lower scores than iced samples. Addition of minced flesh tended to lower the desirability scores. However, nearly all samples retained good desirability scores'. (greater than 7.0) throughout 220 days at -18°C. The lowest mean score (4.9) was for the 6-day RSW sample with 30% mince at 375 days of frozen storage. The significant interaction between storage time and medium was probably a result of the lack of a significant difference between desirability scores of iced and RSW samples at 220 days of frozen storage (Table 12). Storage medium did affect desirability scores at other storage times. Desirability scores were significantly correlated with all other sensory attributes for samples held in ice with the highest correlation coefficient being with texture (Table 10). For RSW samples, mean desirability scores were significantly correlated with other sensory attributes except color. Both flavor and texture scores had high correlation coefficients with desirability scores for fish held in RSW. The control samples held at -34°C showed essentially no changes in DMA, expressed thaw drip, or desirability (Table 16).

CONCLUSION

Blocks containing up to 30% mince were rated as having very acceptable quality if prepared from fish held to 6 days in ice and to 4 days in RSW. Although fried portions from blocks prepared from pollock held 6 days in RSW were given good flavor and desirability scores, the presence of off odors of the raw flesh indicated the quality was borderline. The blocks with 15% added mince were on the whole slightly lower in quality than the blocks with no mince but were still very acceptable. The blocks with 30% mince **were** tougher and drier than the blocks with 15% mince but were not significantly lower in overall quality. Quality of blocks with or without added mince remained highly acceptable to 7 months of frozen storage at -18°C and was slightly lower but still acceptable at 12 months. Adding mince to the fillet blocks did not accelerate the normal toughening of pollock flesh during frozen storage. Samples from fish held in ice had better quality than from fish held in RSW.

The toughest texture which accompanied frozen storage was probably due to the reaction of muscle proteins with the FA which is produced along with DMA in the breakdown of TMAO. The rate of DMA formation was higher for samples prepared from fish held in RSW but-was not influenced by the time of fresh holding or the addition of mince. More DMA was probably formed in blocks containing minced flesh during the freezing process, however. Expressed thaw drip was lower for samples from RSW than for samples from iced pollock but otherwise changed in the same manner as DMA content. The control samples held at -34°C showed essentially no changes in DMA, expressed thaw drip, or desirability.

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Table 1.--Moisture, salt, trimethylamine (TMA), dimethylamine (DMA), trimethylamine oxide (TMAO), and protein content of fillets from fish held in ice or refrigerated seawater (RSW).

Medium	Time of holding (days)	Moisture (4)	NaCl (2)	TMA	DMA	TMAO	Protein (%)
				(mg N/100 g flesh)			
	0	82.25	0.10	0.20	0.83	61.2	14.5
Ice	2	82.19	0.10	0.26	0.98	67.0	17.3
	4	83.13	0.12	0.27	0.91	61.4	14.3
	6	82.85	0.15	0.70	1.48	59.1	17.1
RSW	2	81.73	0.27	0.23	1.04	62.1	17.6
	4	81.41	0.47	1.24	1.09	60.7	17.4
	6	82.01	0.60	4.28	2.20	55.1	16.5

Table 2.--Change in dimethyalmine (mg N/100 g) content in modified pollock blocks during frozen storage at -18°C.

Mince (%)	Medium	Holding time (days)	Storage time (days) 30	90	220	375
0		0	1.80	2.56	5.43	6.92
	Ice	2	1.24	2.74	2.71	5.52
		4	1.82	2.86	3.91	4.54
		6	1.71	3.14	5.50	5.89
	RSW*	2	2.00	3.20	3.84	6.68
		4	2.18	4.45	5.34	7.52
		6	2.12	2.45	3.98	5.48
15		0	1.81	3.57	7.92	7.98
	Ice	2	1.24	3.47	3.25	5.16
		4	2.10	3.59	3.37	5.44
		6	1.64	3.67	4.91	5.77
	RSW	2	1.90	3.31	4.59	6.62
		4	1.98	4.04	5.40	6.48
		6	2.37	3.37	4.25	5.40
30		0	2.16	3.69	5.56	8.14
	Ice	2	1.66	3.18	3.69	6.61
		4	2.15	3.43	3.69	6.40
		6	1.69	3.20	5.98	7.78
	RSW	2	1.86	3.37	4.38	7.54
		4	2.34	3.78	5.04	6.62
		6	2.25	4.27	4.53	6.97

* Refrigerated seawater.

Table 3.--Analysis of covariance of the regression of dimethylamine content on time of frozen storage (S) of modified pollock blocks with medium (M), time of holding (H), and block form (B) as covariants.

Model	Sum of squares	df[a]	Mean square	F	Probability[b]
Saturated	0.88405	20			
Additive	0.85018	8			
S		3			
M		1			
H		2			
B		2			
Interaction	0.03387	12	0.002823	2.87	<0.010
M x H	0.02132	2	0.010660	10.85	<0.001
M x B	0.00275	2	0.001375	1.40	ns
H x B	0.00817	4	0.002043	2.07	ns
M x H x B	0.00164	4	0.000410	0.42	ns
Error	0.11595	118	0.000983		

[a] df = degrees of freedom.

[b] Probability that F is not significant, ns ($P<0.05$).

Table 4.--Analysis of covariance of the regression of dimethylamine (DMA) content on time of frozen storage (STIME) of modified pollock blocks held in ice or refrigerated seawater (RSW), with holding time (HTIME) and block form (BLOCK) treated as covariants.

Model	Sum of squares	df[a]	Mean square	F	Probability[b]
ICE					
Saturated	0.84911	19			
Additive	0.84576	7			
STIME	0.77105	3	0.25702	81.75	<0.001
HTIME	0.03738	2	0.01869	5.95	<0.010
BLOCK	0.03733	2	0.01867	5.94	<0.010
Interaction	0.00335	12	0.00028	0.09	ns
Error	0.15089	48	0.00314		
RSW					
Saturated	0.91478	19			
Additive	0.89884	7			
STIME	0.87222	3	0.29074	174.00	<0.001
HTIME	0.02240	2	0.01120	6.70	<0.005
BLOCK	0.00422	2	0.00211	1.26	ns
Interaction	0.01594	12	0.00132	0.79	ns
Error	0.08522	51	0.00167		

[a] df = degrees of freedom.

[b] Probability that F is not significant, ns ($P<0.05$).

Table 5.-Analysis of covariance of the regression of dimethylamine (DMA) content on time of storage (STIME) of modified pollock blocks, with medium (MEDIA) and time of holding (HTIME) as covariants.

Model	Sum of squares	df[a]	Mean square	F	Probability[b]
0% mince					
Saturated	0.88423	12			
Additive	0.82803	6			
STIME		3			
MEDIA		1			
HTIME		2			
Interaction	0.05621	6	0.009368	2.75	<0.05
Error	0.11577	34	0.003405		
15% mince					
Saturated	0.84710	12			
Additive	0.81596	6			
STIME	0.81596	3	0.27199	61.96	<0.001
MEDIA	0.01661	1	0.01661	4.15	<0.050
HTIME	0.00439	2	0.00220	0.55	ns
Interaction	0.02083	6	0.00347	0.88	ns
Error	0.13207	33	0.00400		
30% mince					
Saturated	0.92038	12			
Additive	0.91469	6			
STIME	0.88995	3	0.29665	123.00	<0.001
MEDIA	0.00276	1	0.00276	1.14	ns
HTIME	0.01437	2	0.00719	2.98	ns
Interaction	0.00570	6	0.00095	0.39	ns
Error	0.07962	33	0.00241		

[a] df = degrees of freedom.

[b] Probability that F is not significant, ns (P<0.05).

Table 6.--Changes in expressed thaw drip (ml/20 g) of modified pollock blocks stored at -18°C;

Mince %	Medium	Holding time (days)	Storage time (days)			
			30	90	220	375
0		0	4.4	5.4	6.7	7.3
	Ice	2	4.1	6.2	6.2	7.5
		4	4.0	5.7	6.6	7.5
		6	5.3	5.4	6.7	7.7
	RSW*	2	4.2	5.7	6.4	7.4
		4	4.0	4.8	6.4	7.2
		6	3.2	5.0	6.1	6.4
15		0	5.2	7.0	7.6	7.4
	Ice	2	4.8	6.6	6.4	7.5
		4	4.8	6.3	7.0	7.4
		6	5.7	6.6	7.0	8.3
	RSW	2	5.1	5.9	6.5	7.8
		4	4.4	4.9	5.9	6.8
		6	3.4	5.4	6.1	6.7
30		0	5.6	6.8	6.8	7.4
	Ice	2	4.9	5.3	6.6	7.7
		4	4.6	5.2	6.8	7.9
		6	4.7	7.0	6.7	8.4
	RSW	2	5.5	6.1	6.8	7.7
		4	4.0	4.4	5.9	6.8
		6	3.6	5.6	5.9	6.6

* Refrigerated seawater.

Table 7.--Mean color scores of portions from modified pollock blocks stored at -18°C.

Mince %	Storage time (days)	Holding time (days) 0	Ice 2	Ice 4	Ice 6	RSW* 2	RSW* 4	RSW* 6
0	30	3.9	3.9	3.7	3.8	3.7	3.7	4.2
	90	3.6	4.6	3.4	4.2	3.4	3.8	3.8
	220	3.9	4.4	3.4	4.2	3.7	3.7	3.9
	375	3.9	4.2	3.7	3.5	3.3	3.7	3.5
15	30	3.8	4.3	3.6	3.7	3.3	3.6	3.3
	90	3.6	3.6	3.6	3.8	3.6	3.5	3.8
	220	3.9	3.7	3.3	3.4	3.9	3.2	3.1
	375	3.8	3.9	3.3	3.8	3.5	3.8	3.2
30	30	3.6	4.1	3.9	3.8	3.6	3.0	3.4
	90	4.3	3.7	4.0	3.3	3.4	3.4	3.7
	220	3.4	3.6	3.3	3.7	3.5	3.9	3.5
	375	3.3	3.2	3.5	3.2	3.5	3.9	3.4

* Refrigerated seawater.

Table 8. -Probabilities* from 4-way ANOVA of sensory analysis data of fried portions from modified pollock blocks. Storage time (STIME) by medium (MEDIA), by holding time (HTIME) by block form (BLOCK).

Source of variation	df	Sensory attributes				
		Color	Flavor	Texture	Juiciness	Desir-ability
STIME	3	0.387	0.000	0.000	0.000	0.000
MEDIA	1	0.014	0.038	0.000	0.723	0.034
HTIME	2	0.156	0.006	0.523	0.061	0.000
BLOCK	2	0.010	0.056	0.000	0.003	0.004
Interactions						
STIME-MEDIA	3	0.558	0.008	0.309	0.022	0.004
STIME-HTIME	6	0.553	0.352	0.637	0.234	0.139
STIME-BLOCK	6	0.897	0.683	0.398	0.573	0.819
MEDIA-HTIME	2	0.042	0.583	0.128	0.283	0.438
MEDIA-BLOCK	2	0.678	0.618	0.214	0.011	0.847
HTIME-BLOCK	4	0.460	0.277	0.459	0.176	0.735
STIME-MEDIA-HTIME	6	0.556	0.927	0.234	0.015	0.322

* Probability that the source of variation (treatment or interaction between treatments> did not affect the scores of a particular sensory attribute. Probabilities less than 0.05 are termed statistically significant. The error term had 648 degrees of freedom (df).

Table 9.--Probabilities[a] from 3-way ANOVA of sensory analysis data of fried portions from modified pollock blocks. Storage time (STIME) by medium (MEDIA), holding time (HTIME) by block form (BLOCK).

Source of variation	df	Sensory attributes: Color	Flavor	Texture	Juiciness	Desir-ability
ICE						
STIME	3	0.170	0.002	0.000	0.008	0.000
HTIME	2	0.007	0.054	0.803	0.743	0.061
BLOCK	2	0.023	0.046	0.091	0.193	0.066
Interactions						
STIME-HTIME	6	0.889	0.701	0.293	0.042	0.227
STIME-BLOCK	6	0.302	0.759	0.230	0.261	0.667
HTIME-BLOCK	4	0.119	0.461	0.348	0.710	0.565
RSW[b]						
STIME	3	0.969	0.000	0.000	0.000	0.000
HTIME	2	0.842	0.060	0.085	0.034	0.002
BLOCK	2	0.256	0.540	0.000	0.000	0.046

Interactions - None were statistically significant.

[a] Probability that the source of variation (treatment or interaction between treatments) did not affect the scores of a particular sensory attribute. Probabilities -less than 0.05 are termed statistically significant. The. error term had 324 degree of freedom (df).

[b] Refrigerated seawater.

Table 10.--Correlation coefficients among color (COLR), flavor (FLVR), texture (TEXT), juiciness (JUIC), desirability (DESR), expressed thaw drip (THAW), and dimethylamine (DMA) content of modified pollock blocks.

	FLVR	TEXT	JUIC	DESR	THAW	DMA
ICE						
COLR	0.415	-0.293	0.127	0.391	-0.360	-0.366
FLVR	-	-0.395	0.260	0.558	-0.631	-0.539
TEXT	-	-	-0.442	-0.688	0.635	0.713
JUIC	-	-	-	0.335	-0.157	-0.273
DESR	-	-	-	-	-0.621	-0.653
THAW	-	-	-	-	-	0.874
RSW						
COLR	0.281	-0.143	0.254	0.240	-0.068	0.018
FLVR	-	-0.731	0.611	0.868	-0.645	-0.832
TEXT	-	-	-0.865	-0.822	0.594	0.762
JUIC	-	-	-	0.652	-0.431	-0.555
DESR	-	-	-	-	-0.686	-0.816
THAW	-	-	-	-	-	0.836

Coefficients with absolute value greater than 0.329 were statistically significant ($P<0.05$). Each coefficient had 34 degrees of freedom.

Table 11.--Mean flavor scores of portions from modified pollock blocks stored at -18°C.

Mince 4	Storage time (days)	Holding time (days)						
			Ice			RSW*		
		0	2	4	6	2	4	6
	30	3.4	3.8	4.1	3.9	4.1	3.8	4.2
	90	3.7	3.9	3.9	4.0	3.8	3.8	3.6
	220	4.0	4.2	3.7	3.6	4.3	3.6	3.7
	3.7 5	3.4	3.7	3.4	3.8	2.9	2.8	3.0
15	30	3.9	4.2	4.1	3.6	3.8	4.0	3.5
	90	3.6	3.6	3.6	3.4	3.8	3.7	3.5
	220	3.7	3.7	3.4	3.4	3.6	3.7	3.2
	375	3.4	3.1	3.7	3.3	2.8	3.0	3.0
30	30	3.5	4.2	3.8	3.8	4.1	3.9	3.6
	90	4.1	4.0	3.5	3.3	4.0	3.5	3,5
	220	3.2	3.4	3.9	3.3	3.5	3.6	3.2
	375	3.4	3.4	4.0	3.2	2,. 9	3.1	3.2

* Refrigerated seawater.

Table 12.-Probabilities* from 3-way ANOVA of sensory analysis data of fried portions from modified pollock blocks. Separate ANOVAs were performed at each period of frozen storage (STIME) by block form (BLOCK), by holding time (HTIME), and by medium (MEDIA).

Source of variation	df	Color	Flavor	Texture	Juiciness	Desir-ability
		Sensory attribute				
STIME = 30 days						
BLOCK	2	0.409	0.730	0.754	0.848	0.766
HTIME	2	0.409	0.201	0.864	0.104	0.682
MEDIA	1	0.036	0.654	0.128	0.250	0.059
Interactions						
HTIME-MEDIA	2	0.561	0.445	0.039	0.034	0.030
STIME = 90 days						
BLOCK	2	0.235	0.195	0.062	0.067	0.070
HTIME	2	0.679	0.151	0.510	0.404	0.149
MEDIA	1	0.160	0.926	0.033	0.286	0.003
Interactions - None were significant						
STIME = 220 days						
BLOCK	2	0.056	0.070	0.060	0.048	0.023
HTIME	2	0.103	0.013	0.380	0.062	0.003
MEDIA	1	0.395	0.737	0.000	0.280	0.546
Interactions						
BLOCK-HTIME	2	0.403	0.212	0.695	0.043	0.778
STIME = 375 days						
BLOCK	2	0.470	0.868	0.001	0.164	0.456
HT IME	2	0.392	0.695	0.428	0.359	0.003
MEDIA	1	0.681	0.000	0.082	0.017	0.020
Interactions - None were significant						

* 'Probability that the source of variation (treatment or interaction between treatments) did not affect the scores of a particular sensory attribute. Probabilities less than 0.05 are termed statistically significant. The error term had 162 degrees of freedom (df).

Table 13.--Mean texture scores of portions from modified pollock blocks stored at -18°C.

Mince %	Storage time (days)	Holding time (days)						
			Ice			RSW*		
		0	2	4	6	2	4	6
0	30	4.0	3.9	4.2	3.9	3.8	3.8	4..3
	90	4.1	4.3	4.1	4.0	3.7	4.0	4.3
	220	4.6	4.0	4.2	4.2	4.4	5.1	4.9
	375	5.0	4.6	4.9	4.9	5.1	4.7	4.7
15	30	4.2	4.1	3.8	4.0	3.9	4.3	4.3
	90	4.2	4.2	4.3	3.9	4.1	4.8	4.6
	220	4.8	4.2	4.5	4.6	4.8	5.0	4.9
	375	4.6	4.8	4.4	5.2	5.1	5.4	5.0
30	30	3.6	4.3	3.9	3.5	4.0	4.4	4.4
	90	4.1	4.1	4.3	4.0	4.8	4.7	4.6
	220	4.3	4.9	4.6	4.6	4.9	4.9	5.3
	375	5.0	5.5	4.9	5.4	5.6	5.4	5.6

* Refrigerated seawater.

Table 14.--Mean juiciness scores of portions from modified pollock blocks stored at -18°C.

Mince %	Storage time (days)	Holding time (days) 0	Ice 2	Ice 4	Ice 6	RSW* 2	RSW* 4	RSW* 6
0	30	3.9	3.7	3.7	3.9	4.8	4.2	4.0
	90	3.7	4.1	4.1	4.1	4.4	4.4	4.3
	220	3.8	4.2	3.7	3.2	4.5	4.2	3.4
	375	3.3	3.7	3.7	3.8	3.8	3.9	3.9
15	30	4.0	4.2	4.4	3.9	4.5	4.0	3.8
	90	3.9	3.8	3.9	4.2	4.3	4.0	4.1
	220	3.8	3.6	3.4	3.2	4.4	3.7	3.3
	375	4.4	4.7	4.4	3.4	3.6	3.1	3.6
30	30	3.1	4.0	4.0	4.3	4.4	3.9	3.8
	90	4.3	3.7	3.6	4.1	3.7	3.6	4.2
	220	3.7	3.4	3.2	3.8	3.2	3.7	3.3
	375	4.2	3.6	4.4	3.2	3.3	3.1	3.4

* Refrigerated seawater.

Table 15.--Mean desirability scores of portions from modified pollock blocks stored at -18°C.

Mince %	Storage time (days)	Holding time (days)						
			Ice			RSW*		
		0	2	4	6	2	4	6
0	30	6.9	6.3	7.9	7.6	8.2	7.8	7.8
	90	7.4	8.1	8.1	7.9	7.4	7.4	7.1
	220	7.5	8.1	7.2	7.2	7.5	7.3	6.8
	375	6.2	6.5	6.0	6.2	5.6	5.9	5.2
15	30	7.3	7.3	7.5	7.4	7.7	7.8	7.0
	90	7.1	7.3	7.9	7.5	6.9	7.4	7.2
	220	6.9	7.0	6.9	6.7	7.5	7.0	7.2
	375	5.8	6.1	6.3	5.4	5.9	6.0	5.4
30	30	5.9	7.1	7.7	7.3	7.9	7.0	7.6
	90	7.8	7.6	7.6	6.9	7.1	7.2	6.7
	220	6.4	6.8	6.9	6.4	7.0	7.2	5.9
	375	5.2	6.0	6.8	5.0	5.1	5.4	4.9

* Refrigerated seawater.

Table 16.-Changes in dimethylamine (DMA); expressed thaw drip, and desirability of pollock fillet blocks stored at -34°C.

Storage time (days)	DMA (mg N/100 g)	Expressed thaw drip (ml/20 g)	Desirability
30	0.94	3.4	8.1
90	1.04	3.9	8.1
220	0.74	4.0	8.0
375	0.74	3.5	7.3

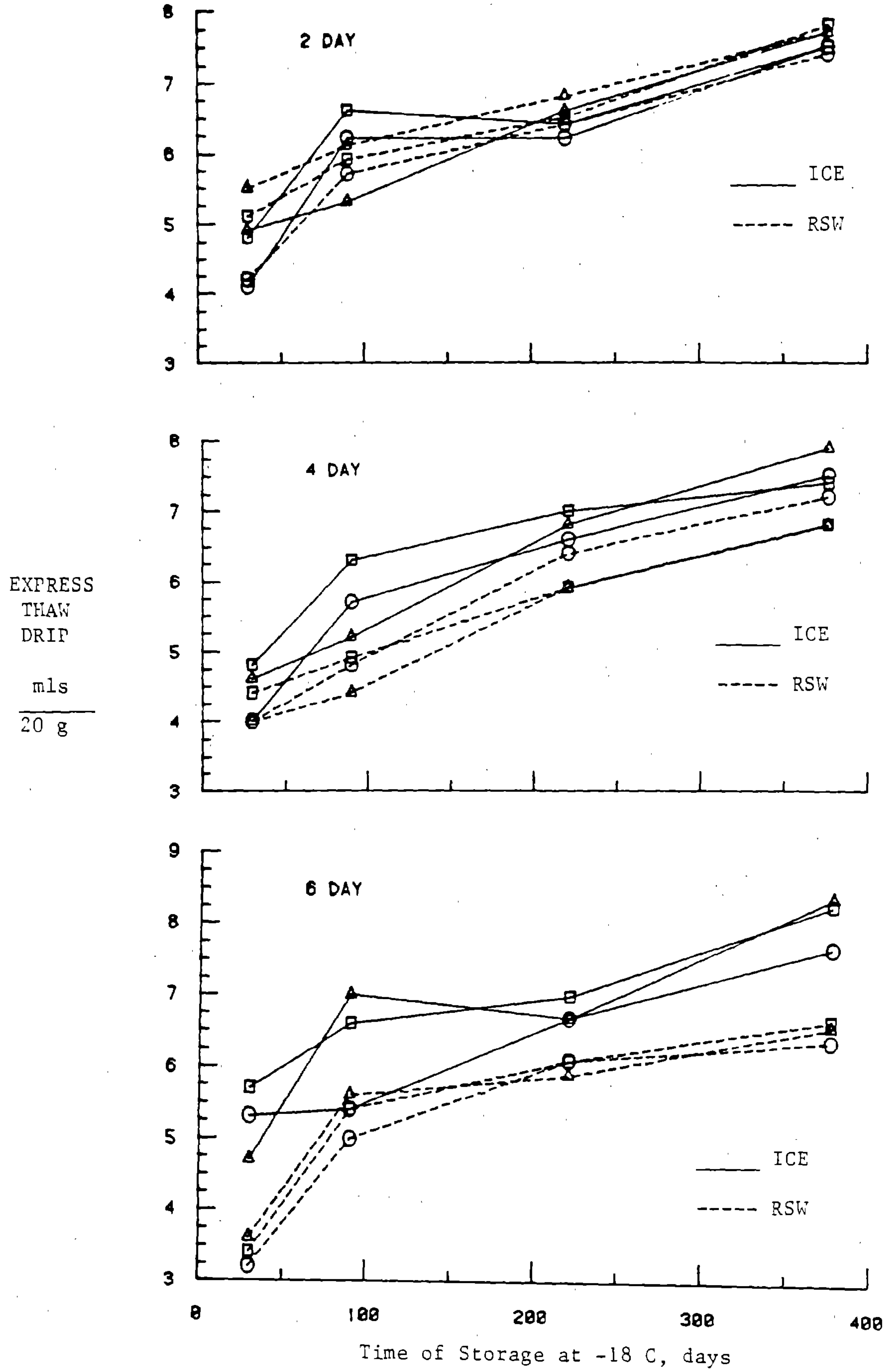

Figure 1.--Change in express thaw drip of modified blocks of pollock fillets containing 0 (O), 15 (a), or 30% (A) minced flesh.